Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

76 of UN cop. 2

Research Note

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE

INTERMOUNTAIN FOREST & RANGE EXPERIMENT STATION
OGDEN UTAH

U.S. Forest Service
Research Note INT-23 1964

TWO AERIAL PHOTO BASAL AREA TABLES

Karl E. Moessner, Research Forester
Division of Forest Economics and Recreation Research

U. S. DEPT. OF AGRICULTURE
NATIONAL AGRICULTURAL LIBRARY
NOV 3 - 1964
CURRENT SERIAL RECORD

ABSTRACT

The two aerial photo basal area tables printed here are based on data from Forest Survey field plots. The tables list average square feet of basal area by total height and crown cover class. Regression formulae and measures of accuracy for the tables are included. Limited tests indicate that estimates based on these tables and direct photo measurements should not differ significantly from estimates of stand basal area obtained by customary ground sampling.

APPLICATIONS

The two basal area tables published here are initial results of efforts to develop practical methods for estimating stand basal area from measurements on aerial photos.

Basal area, long considered the simplest and most stable indicator of stand stocking, is widely accepted by timber managers as the best measure of levels of growing stock. Few forest management inventories fail to estimate basal area, particularly in younger stands, and many compute it as one step in volume estimating.

Since 100-percent measurement of all trees in the stand is rarely justified, most estimates of basal area are obtained by sampling. The high cost of ground sampling in all forest measurements limits the number of plots that can be used and consequently limits precision of estimates. Aerial photographs, however, provide opportunity to reduce costs greatly and at the same time to produce estimates of stand basal area reliable enough for most management inventories.

The two tables published here use photo measurements of average stand height and crown cover to estimate basal area of a stand. Techniques of measurement have been described previously.[1]

The literatures of photo interpretation and forest mensuration contain some discussion of photo measurements that might be useful in estimating basal area, but they contain no usable tables. For example, Spurr[2] wrote that "basal area is, theoretically, roughly proportional to percent crown closure for a given species and height class." He admitted, however, that "previous efforts to quantify this relationship have yielded poor results."

The Society of American Foresters Committee on Forest Mensuration Problems,[3] discussing photogrammetry under forest surveys, says "we must develop methods of precisely measuring crown density on aerial photos, and these should be more closely related to total basal area or the volume of forest stands." Apparently the committee feels that the widely used crown coverage scales are too subjective for this purpose.

There is, however, support for the use of crown coverage as a photo measure of basal area. In a paper on aerial volume tables,[4] limited analysis showed relatively good correlation (0.810 on 20 sample plots) between percent crown cover measured on aerial photos and the percentage that field basal area is of the yield table basal area for fully stocked stands. In this study the yield table was entered with a site estimated from aerial photos and a stand age estimated from the photo measurement of stand height. Other photo interpreters have noted the relation between crown cover measured on photos and basal area and have used crown cover as an independent variable in aerial photo volume tables for this reason; but few seem to have tried predicting basal area itself from the photo measurements.

Reliability of estimates made with the two following tables is indicated by the standard measures of accuracy included with the equations, and by the results of several tests described later that were made independently of the basic tabular data.

CONSTRUCTION OF THESE TABLES

The photo basal area tables published here were compiled from:

1. A total of 145 samples obtained from 16-point multiple plot grids measured on the St. Regis unit of the Coeur d'Alene National Forest, Montana. These plots are typical of the white pine and other mixtures found in the northern Rocky Mountains.

2. A total of 85 samples from 10-point multiple plot grids measured on the Coconino National Forest in Arizona, and typical of the ponderosa pine stands found in the Southwest.

---

[1] Moessner, Karl E. Training handbook: basic techniques in forest photo interpretation. U.S. Forest Serv. Intermountain Forest and Range Expt. Sta. 73 pp., illus. 1960.

[2] Spurr, Stephen H. Photogrammetry and photo-interpretation. Ed. 2, 472 pp., illus. New York: Ronald Press. 1960.

[3] Honer, T. G., and L. Sayn-Wittgenstein. Report of the committee on forest mensuration problems. Jour. Forestry 61: 663-667. 1963.

[4] Moessner, Karl E. Aerial volume tables for conifer stands. (Unpublished paper presented at Western Forestry Conference, Victoria, B.C., 1956.)

AERIAL PHOTO BASAL AREA TABLES FOR MIXED SPECIES, NORTHERN ROCKY MOUNTAINS [1]

Gross basal area[2] per acre by average stand height and crown cover

Stand height[3] (feet)	Crown cover[4] (percent) 5	15	25	35	45	55	65	75	85	95
	Square feet									
15	18	14	10	7	4	2	--	--	--	--
20	20	17	14	12	11	9	9	9	9	9
25	22	20	18	17	17	17	17	18	19	21
30	24	23	22	22	23	24	25	27	29	32
35	26	26	26	27	29	31	33	36	40	44
40	28	29	30	33	35	38	42	46	50	55
45	30	32	35	38	41	46	50	55	61	67
50	31	35	39	43	48	53	58	65	71	78
55	33	38	43	48	54	60	67	74	82	90
60	35	41	47	53	60	67	75	83	92	101
65	37	44	51	58	66	75	83	93	102	113
70	39	47	55	63	72	82	92	102	113	124
75	41	50	59	69	79	89	100	111	123	136
80	43	53	63	74	85	96	108	121	134	147
85	45	56	67	79	91	104	117	130	144	159
90	47	59	72	84	97	111	125	140	155	170
95	49	62	76	89	104	118	134	149	165	182
100	52	65	80	95	110	126	142	159	176	193
105	54	69	84	100	116	133	150	168	186	205
110	56	72	88	105	123	140	159	178	197	217
115	58	75	92	110	129	148	167	187	207	228
120	60	78	96	116	135	155	176	196	218	240
125	62	81	101	121	141	162	184	206	228	251
130	64	84	105	126	148	170	192	215	239	263
135	66	87	109	131	154	177	201	225	249	274
140	68	90	113	137	160	185	209	234	260	286
145	70	94	117	142	167	192	218	244	271	298
150	72	97	122	147	173	199	226	253	281	309
155	74	100	126	152	179	207	235	263	292	321
160	76	103	130	158	186	214	243	272	302	333
165	79	106	134	163	192	222	252	282	313	344
170	81	109	139	168	198	229	260	292	324	356

[1] Based on 145 sample locations measured on Coeur d'Alene National Forest, Montana.

[2] Basal area of all trees 5.0 inches d.b.h. and larger, computed from Forest Survey multiple point sample locations.

[3] Average height of the stand, photo measurement checked in the field.

[4] Crown cover of the stand, photo measurement.

Basal Area Equation

$BA = 0.24701H - 0.77068C + 0.02116HC + 0.00014H^2 + 0.00231C^2 + 15.92380$

Where BA = basal area per acre in square feet; H = stand height in feet; and C = crown closure in percent.
Multiple correlation coefficient (R) = 0.710. Aggregate deviation. Table 0.0003 percent high.
Standard error of estimate = ±31 square feet or ±52 percent of the mean plot basal area.
Forest Survey, Intermountain Forest and Range Experiment Station, Ogden, Utah, 1964.

AERIAL PHOTO BASAL AREA TABLES FOR PONDEROSA PINE IN THE SOUTHWEST [1]

Gross basal area[2] per acre by average stand height and crown cover

Stand height[3] (feet)	Crown cover[4] (percent)									
	5	15	25	35	45	55	65	75	85	95
	Square feet									
20	23	32	40	48	58	71	89	110	135	163
25	23	32	41	48	59	74	92	114	140	169
30	24	33	41	49	61	76	96	119	145	176
35	24	33	41	50	63	79	100	124	151	182
40	24	33	41	51	65	83	104	129	157	189
45	25	34	42	53	68	86	108	134	163	197
50	25	34	42	55	70	90	113	140	170	204
55	25	34	44	57	73	94	118	146	177	212
60	26	35	45	59	77	98	123	152	184	220
65	26	35	47	62	80	103	129	159	191	228
70	27	36	49	65	84	107	134	165	199	237
75	28	38	51	68	88	113	140	172	207	246
80	29	39	53	71	93	118	147	179	215	255
85	30	41	56	75	97	124	153	187	224	265
90	31	43	59	79	102	129	160	195	233	274
95	32	46	63	83	108	136	167	203	242	284
100	34	48	66	88	113	142	175	211	251	295
105	39	51	70	93	119	149	182	220	261	305

[1] Based on 85 sample locations measured on the Coconino National Forest, Arizona.

[2] Basal area of all trees 5.0 inches d.b.h. and larger, computed from Forest Survey multiple point sample locations.

[3] Average height of the stand, photo measurement checked in the field.

[4] Crown cover of the stand, photo measurement.

Basal Area Equation

$$BA = -0.81620H - 0.83765C + 0.01902HC + 0.00545H^2 + 0.01831C^2 + 55.32472$$

Where BA = basal area per acre in square feet; H = stand height in feet; and C = crown closure in percent.

Multiple correlation coefficient (R) = 0.840. Aggregate deviation: Table 0.0002 percent high.

Standard error of estimate = ±20 square feet or ±38 percent of the mean plot basal area.

Forest Survey, Intermountain Forest and Range Experiment Station, Ogden, Utah.

These tables relate stand basal area per acre obtained from field measurements to aerial photo measurements of:

1. Average total height of the dominant stand.--This measurement, although made on photos, was checked by comparing it with the average height of the dominants and codominants measured on the ground. Plots with unreconcilable differences between photo and ground measurements were eliminated.

2. Crown coverage of the stand.--This measurement was made only on photos since readings of what the interpreter sees cannot be obtained as precisely on the ground.

Average crown diameter was also measured on photos and tested as a variable, but was not used in constructing these tables.

Basal areas were computed for all live trees 5.0 inches d.b.h. and larger using measurements from the multiple field plots. For the St. Regis data, the per-acre estimate of basal area was obtained from measurements on sixteen 1/256-acre fixed plots for all trees up to 10.9 inches d.b.h., and on 16 variable-radius plots for all trees 11.0 inches and larger. Basal area was measured with a 75-factor prism. For the Coconino National Forest data, the multiple grid included 10 locations, and all trees 5.0 inches d.b.h. and larger were measured on variable plots using a 40-factor prism.

Those plots interpreted on aerial photos as two-storied were treated somewhat differently. Photo and field measurements for each story were used as independent samples. In using the table, the total basal area for a stand classified on photos as two-storied is the sum of the basal areas for both stories.

The tables were constructed by machine compilation using multiple regression analysis. The basic independent variables tested were the stand variables commonly measured on aerial photos: average total height (H), crown cover (C), and average crown diameter (D). Stepwise regression analysis indicated best results were obtained from the first equation (total height and crown cover) and that powers higher than squares were of little advantage. For this reason, the tables produced were prepared from total height and crown cover and their squares and cross products.

The basal area equation and the standard measures of accuracy accompany each table. The standard error of estimate for each table is based on the field plot data used in preparing the table. For each sample, the dependent variable (BA) is an average based upon either 10 or 16 subsamples. Hence, the residual error (standard error of estimate) includes both the error of the mean of the subplots measured on the ground and the error introduced by the regression of basal area to the photo measurements of total height and crown cover. In short, the table may provide estimates closer to the true basal area per acre than is indicated by the published residual error.

TESTS OF THE TABLES

Several empirical tests were made of the tables using field plot data that were not used in preparing the tables. These data came primarily from the files of Forest Survey. Per-acre estimates from ground measurements of 1/5-acre, 1/4-acre, variable radius, and 10-point locations were used in the comparisons. These tests indicate the comparative precision and accuracy of basal area estimates made wholly through photo measurement. Tests based on the means of 5-plot random groups indicate the relative accuracy of stand estimates made with few plots. Five-plot means were used because available data were limited, and because field estimates are often based on this small a number.

Results of the tests of the northern Rocky Mountain table are shown in the following tabulation.

Test	N	Basal area per acre (means and their standard errors)		Individual estimates: Standard error of estimate			Individual estimates: Coefficient correlation
		Photo	Field	Sq. ft.		Percent	
		- - Square feet - -					
Individual plots							
North Idaho Forest Survey							
1/5-acre field plots	51	101± 8	[1] 119±13	±63	or	±53	0.785
Gravy Creek Timber Sale							
Variable plots (sawtimber only)	26	85± 5	89± 9	±33	or	±37	0.681
5-plot random groups							
North Idaho plots	10	99±11	[1] 118±15	±32	or	±27	0.838
Gravy Creek Sale	5	88± 7	92± 8	±14	or	±16	0.584

[1] Difference between field and photo estimates of basal area significant at 95-percent level.

Although the photo and field estimates from the 51 fixed 1/5-acre plots in northern Idaho are significantly different (see tabulation above), the correlation is high and adjustment of differences could be made easily by means of a few field plots.

In the second test, photo and field estimates of sawtimber basal area from the 26 variable-radius plots on the timber sale cruise are very close, and the standard error of estimate of the individual plots is only one-half that of the fixed 1/5-acre plots.

In both tests, computations based on the mean of 5-plot groups cut this standard error of estimate in half and indicate the table should work well in estimating average basal area per acre for stands.

Several tests were also made of the basal area table for ponderosa pine in the Southwest. These tests were based on standard 1/4-acre plots as well as on the new 10-point multiple locations. The following tabulation summarizes results of these tests.

Test	N	Basal area per acre (means and their standard errors)		Individual estimates		
				Standard error of estimate		Coefficient correlation
		Photo	Field			
		- - Square feet - -		Sq. ft.	Percent	
Individual plots						
Coconino National Forest (10-point locations)	52	78±5	70±5	±32	or ±46	0.673
Forest Survey, Arizona (10-point locations)	45	75±5	73±6	±37	or ±51	0.505
Coconino National Forest (1/4-acre plots)	52	78±5	70±6	±39	or ±55	0.567
Navaho Indian Reservation (1/4-acre plots)	26	48±5	[1] 58±5	±23	or ±39	0.637
5-plot random groups						
Coconino National Forest (10-point locations)	10	78±6	[1] 69±6	±15	or ±22	0.802
Forest Survey, Arizona (10-point locations)	9	75±3	73±5	±9	or ±12	0.851
Coconino National Forest (1/4-acre plots)	10	78±6	70±5	±14	or ±20	0.796
Navaho Indian Reservation (1/4-acre plots)	5	48±6	[1] 58±6	±13	or ±13	0.933

[1] Difference between field and photo estimates of basal area is significant at 95-percent level.

Most of these photo and field estimates of basal area are not significantly different even though fieldwork was performed under supervision of three different agencies, namely, the Navaho Indian Reservation, the Coconino National Forest, and the Forest Survey, Intermountain Forest and Range Experiment Station. Results from use of the 10-point locations and 1/4-acre plots were comparable.

Significant improvement in standard error of estimates and in simple correlation was again obtained by using the means of randomly selected 5-plot groups.

In summary, we feel these various tests strongly indicate that basal area of stands can be satisfactorily estimated from photo measurement, and that the photo basal area tables published here will work well on many management inventories.